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The American Institute *of* Consulting Engineers, Inc.

ABSTRACT OF DISCUSSION ON THE SUBJECT

of

THE PRINCIPLES AND BROAD ECONOMICS OF HIGHWAY DESIGN AND CONSTRUCTION

At a Special Meeting held October 13th, 1920

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Abstract of Discussion on the Subject of the Principles and Broad Economics of Highway Design and Construction

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Mr. Whinery:

The demand for good roads is almost universal, and the expenditure for them has, for the last few years, been on an enormous scale. It was officially stated early in the season that the sum of $663,000,000 was provided for and would be available for road improvements during this year, in the continental United States. When it is considered that this sum is equal to about $6.25 per capita of the whole population the very great importance, both financially and economically of the subject may be appreciated.

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In no other department of Engineering, has so little been done in the investigation by accurate scientific research and experiment, of the basic facts and principles relating to highway design and construction.

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It is true that a great mass of miscellaneous literature on highways has accumulated in Engineering and other society proceedings, in public reports and in the technical press; but the enquiring reader will find in it very little definite and trustworthy data based upon adequate modern methods of investigation and experiment.

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The bare facts that one steel highway bridge of given span and depth of truss failed under stresses, loosely designated as heavy traffic, while another of like dimensions, and also subjected to alleged heavy traffic remained in good condition, conveys no information of value to the modern bridge engineer. And yet this is not a greatly exaggerated illustration of the character of much of our highway literature.

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It should go without saying that successful progress in highway, as in other departments of engineering must be founded upon a full and accurate knowledge of the physical and mechanical properties of the materials or combination of materials to be used, their relations to each other, and the nature and magnitude of the service to be provided for. As well might we undertake to design a bridge without a knowledge of the properties and strength under all conditions of use, of steel, or in ignorance of the service to which it will be subjected. Successful engineering requires also a knowledge and consideration of the economic questions and problems involved in any public work or enterprise with which it undertakes to deal. In fact the economic phases of a public enterprise are fundamental and take precedence of the engineering problems, the primary question in the great majority of cases being: How may the best results be fully secured with the least expenditure of money, whether in construction or maintenance.

The bald statement, not infrequently heard, that considering their short life and the money invested in them, our new highways are economic failures, is, of course, untrue, but it contains enough of truth to challenge our serious consideration, and our best efforts to make it groundless in the future. Within certain limitations we should be able, and the public may reasonably expect us to design and construct highways with something like the same success and certainty of results that characterizes our work in other departments of engineering.

The first and most important step toward such an achievement will logically be a thorough investigation by systematic scientific research, experiment and analysis of all the factors and conditions entering into the problem. The results of such a technical investigation, checked and reinforced by our practical past experience, should not only disclose the chief causes of past failures but supply us with a body of data the intelligent use of which should enable us to design and construct public roads that will adequately meet the requirements of the service for which they are intended.

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Bearing in mind that the controlling requisites for a successful highway are that as a structure it shall have the strength safely to carry the loads to which it will be subjected, and a surface capable of best resisting disintegration or abrasion of travel, and that, regarded as an investment, it shall yield a reasonable return in service upon its cost, these elements would probably receive the first attention in such an investigation.

Experience seems to prove that the chief cause of failure in the past has been inadequacy of supporting power, or, in other words weakness of foundation. The roadway structure proper rests upon the earth subfoundation, and our practice in the past and at present assumes, tacitly at least, that this subfoundation is homogeneous, of uniform bearing capacity, and capable of carrying and distributing the loads transmitted to it by the overlying foundation proper. But the fact is, as we all know, that such an assumption is unwarranted. The character and bearing capacity of natural surface soils may vary greatly and change quite abruptly. Where grading is necessary as is nearly always the case, excavation in spots may be carried too deep and refilling imperfectly compacted. Embankments are seldom so built up as to be of uniform density, and where pipe laying or other underground work is necessary the trenches are very seldom properly back-filled. It is in short practically impossible by ordinary methods to secure a subfoundation of uniform density and bearing capacity.

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Another matter of very great, but not perhaps of equal importance to adequate foundations, is that of a wearing surface that will most efficiently and economically resist the *abrasion* of travel. In regard to this our experience has been very deficient and unsatisfactory. I have long believed that investigations and experience will ultimately develop that a comparatively thin and inexpensive surface coating of bituminous material of the right composition and consistency applied in the proper way to a concrete surface of such character as to secure effectual adherence, will give the best results.

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An experimental investigation under competent direction, would throw great light on this important element, and lead to the saving of vast sums in the cost of highway maintenance. Another matter that has become of pressing importance in quite recent years and is certain to become more so in the future, is the relation between the strength and endurance of highways and the loads permitted over them. The introduction and rapid increase of heavy power trucks in highway transportation has made necessary a radical revision of the ideas prevailing only a few years since regarding the strength of foundation necessary to be provided. A great number of highways built only a few years since and believed then to be amply strong to withstand any travel likely to come upon them, have been quickly destroyed by this new kind of vehicle, and must be practically reconstructed. This is not surprising when we reflect that vehicles are in common use that with their nominal load of say 7½ tons impose upon the roadway a wheel-load of from 9,000 to 10,000 lbs. concentrated upon a comparatively small area, and that they are frequently overloaded to the extent of 50% or more. Even the 5-ton truck is not infrequently so loaded as to exert a rear wheel pressure of seven or eight thousand pounds. The question now of pressing importance is: Shall roads be designed and built with sufficient strength to carry these concentrated loads, or shall the permissible wheel-loads be strictly limited?

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There must be some limit beyond which it will be not merely uneconomical but impossible to increase the cost of our highways, which are already approaching the prohibitory line. According to the newspaper reports the State Highway Commission of New Jersey has seriously considered and barely rejected bids for certain trunk highways at the rate of $125,000 or more per mile. When it is remembered that very few of our trunk line railroads cost more than about half that sum per mile, the question may well be raised whether we can afford to invest such vast sums of money in our public roads.

If we are to double or quadruple the cost of our roads for the benefit of the power trucks and pleasure travel, should not the excess cost be largely specially assessed upon those for whose benefit it is incurred? And if this be answered in the affirmative how may this purpose be best practically accomplished? And if accomplished what effect will it have upon the cost and economy of highway transportation by the power truck?

Considered from any point of view the colossal importance financially, industrially and commercially of these matters, calls for the most thorough investigation by scientific methods with the least possible delay. Such an investigation is an appropriate and proper function, if not a positive duty, of the Federal Government. Considering its importance its cost would be a mere bagatelle compared with its value. A comparatively small fraction of the sums now being appropriated for federal-aid highway construction work would be ample for the purpose. The work could be devolved upon some one of the departments or bureaus organized and equipped for such scientific and economic investigation, but it should be undertaken and carried out under the supervision of a board, or commission composed of men specially fitted by ability, knowledge and experience to deal with the subject involved.

MR. WHINERY submitted the following resolution:

WHEREAS, The design, construction and maintenance of highways is one of the most important matters now occupying the attention of the American people, and the money expended annually for highway improvement aggregates an enormous sum; and

WHEREAS, Experience has demonstrated that a large majority of the new and improved highways built in the past under designs, specifications and methods still being largely adhered to, are inadequate in strength and endurance to withstand the weight and density of the travel, and their consequent rapid disintegration and failure results in great financial and economic loss; and

WHEREAS, The present extensive use of heavy power trucks, a use likely to largely increase in the future, imposes a new and very destructive element upon the highways, making more necessary and urgent a revision of the theory and practice heretofore prevailing; and

WHEREAS, The unsatisfactory and costly experience of the past has been largely due to the lack of accurate data relating to the physical, mechanical and economic problems involved, such as has been accumulated by adequate scientific investigation in other departments of engineering work; and

WHEREAS, The great financial and economic magnitude and importance, and nation-wide character of this department of public work, warrants and demands the most careful research and study, and such research is an appropriate and proper function of the National Government, therefore be it

Resolved, That the Federal Congress be petitioned and strongly urged to authorize such research, scientific investigation and physical experimentation as may be necessary to supply the data needed for the intelligent and economic design, construction and maintenance of highways; and to make an adequate appropriation therefor. Such investigation to be made either by the Bureau of Highways or by the Bureau of Standards under the supervision of an advisory board composed of three specialists in highway engineering, appointed by the President of the United States from a list of not less than ten, to be nominated by Engineering Council or a body that may succeed it in similar functions.

Resolved, That the co-operation and active aid of other engineering, technical, economic and commercial organizations, the Highway Commissioners of the several states, and the technical press, be requested and urged in securing the early inauguration and furtherance of the action herein recommended.

MR. CHAS. J. BENNETT, Highway Commissioner of Connecticut:

In what I have to say I want to approach this problem from the standpoint of traffic—the development of traffic. You realize, of course, that we have a tremendous traffic over our roads in the country, and that traffic is confined to the improved roads which are a very, very small percentage of the whole mileage. I take it that there are not more than 5 or 6% of the total mileage of interurban roads in the United States that are hard-surfaced.

On that system of highways we have a traffic concentrated which is far in excess of the traffic in France, and about equal to that in England,—England, however, being far beyond us in the development of highways.

I would like to give you just a few specific figures as to concentration of traffic on certain highways. Take, for instance, on the Boston Post Road, between New York and New Haven. In three days,—Saturday, Sunday and Monday, starting at twelve o'clock on Friday night, and ending up at twelve o'clock on Monday night, there was a total of 20,000 vehicles passed over that road—16 feet in width, of a hard-surfaced pavement.

Now, you can reduce that to any sort of figures that you care to. You can average it over any hour—something over 200 every hour, or you can take a peak, certain hours where there were 800 vehicles passing in both directions over that narrow road. Now you can see that that is an indication of an increase in traffic.

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In the total year the average of that road was 157,000 vehicles for the 12 months in the year, every vehicle that passed over it.

In that whole year there were 7,000 heavy trucks, that is, trucks in excess of 3 tons capacity, and 8,400 less than 4 tons in capacity. There were 700 in excess of 4½ tons capacity.

The excess cost of these roads mentioned by Mr. Whinery is due to a great extent to the motor truck.

The amount of money that has to be put in the improvement and construction to take care of 700 vehicles is out of all proportion to the use that they give the highway. Connecticut is a manufacturing state, with its population concentrated on highways and railroads and not spread abroad as in some of the agricultural states, so that we have a problem, a definite problem,—congestion of traffic—solution of the question of what to do with the motor truck,—and one other thing that has not been touched upon in Mr. Whinery's discourse, and that is, the need of extending the highway system beyond what is already improved.

Now, before I go on with that I just want to say a word about this truck matter. There is a pamphlet issued to-day, entitled: "Clouds on the transportation horizon." I won't take the trouble to go into details, but I call your attention to the fact that it says here that one state's license fee for a 7½-ton truck is $1,225 and this pamphlet puts an anathema on any such license, and I say a $1,225 license is no more than fair for a truck that does the damage that a 7½-ton truck does at certain times of the year. Reduced to cost per mile of service of that truck, $1,225 license fee will be less than 2c per ton mile on the cost of carrying freight, basing the truck on a 300 day year, a 40-mile day load, with a rated capacity of 7½ tons.

Then to go on for just a moment on the question of economics—what we should do in order to solve this problem. There are two or three things that are evident, it seems to me. The first one is that there is a limit to the amount of money that we can secure for the improvement of highways, and we are pretty nearly at the limit, with $600,000,000 available.

The second question is: Shall that money be spent in the construction of hard-surfaced roads on a limited number of miles to accommodate one class of traffic, a very small class, or shall it be used reasonably in the extension of the highway systems that we already have?

It seems to me that somewhere there must be an extreme beyond which the motor truck can't go, and at which we can stop and design a road suitable to carry the loads to which it is to be subjected, but we must know those loads, and we must know the limit of those loads, and we must know how long that limit is going to obtain. It is not for this year, nor for next year, but for the life of the road, and until we can answer some of those questions, we will still come to you gentlemen, —the Highway Commissioners of this country will still come to you gentlemen with something in the way of an apology for not having solved the tremendous problem.

MR. CHAS. W. LEAVITT said in part:

A solution to that problem might be found in many ways, but I think one solution is found in following the example of the Pennsylvania Railroad, where the traffic became so intense that they sent the freight over another route, taking away from the congested line the slow moving traffic and conducting it by a more direct route to the point where the through carloads were desired. If, instead of going through congested towns, a well-equipped highway could be built on a more direct route, and slow moving traffic turned over it, with proper taxation for the use of that road by the people who are moving freight by motor vehicles, it might relieve some of the towns and safeguard them against the deterioration in value of real estate, which I feel quite sure will come from this misuse of the highways.

MR. M. O. ELDREDGE, Director of Roads, American Automobile Association:

During the past fifteen years we have spent about $3,000,000,000 on the public roads of the United States and during that time we have only increased our mileage of durable types by about 12,500 miles. In other words, we have added that mileage to our total of durable types which is scarcely one-half of one per cent. of our total mileage.

It should be said, however, in justice to those who have charge of the administration of the Federal Aid Act that only 35% of the money,—the Federal aid money—is being applied to the less durable types.

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It is realized, of course, that the grading of a dirt road is a substantial improvement—there is no doubt about that—and it is argued in some of the states that the building of one thousand miles of dirt road would be of greater advantage to the people than the building of one hundred miles of durable type, such as concrete, brick or bituminous.

Representatives of the National Automobile Chamber of Commerce, the American Automobile Association and other organizations met with representatives of State highway departments about a year ago and prepared a uniform vehicle law in which they recommended that the maximum weight of a truck should be 28,000 pounds—800 pounds per inch width of tire on the rear wheels.

The chances are that ultimately all of our highways will have to be classified into roads which will carry the 28,000 pound loads and other roads on which such concentrated loads cannot be carried at all seasons.

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The best solution of our highways problem, in my opinion, will be found in the building of a system of National or interstate roads constructed and maintained by or under the direction of the Federal Government, such a system to be coordinated with state and county roads, built and maintained by the states and counties.

MR. P. W. HENRY:

Having been interested in road construction for some years prior to 1908, I presented a paper to the First International Road Congress, devoting most of it to the wearing surface, but alluding briefly, to the important part played by subdrainage and foundation.

My point at that time, as it is now, was to emphasize the importance of subdrainage, which is necessary for light, as well as for heavy, traffic, and to the necessity of a foundation suitable for the traffic, leaving only the wearing surface to be renewed from time to time. This means that in building a gravel or macadam road for light traffic, consideration should be given to the use of these materials later on for the foundation of a heavier traffic construction, especially where there is a probability of increased traffic.

Ordinarily it should not be necessary to tear up a macadam road and replace it with concrete, for I have known many instances where a well-built macadam has afforded an excellent foundation for an asphalt or bituminous wearing surface. To mention only two cases, an asphalt wearing surface of from 2½ to 3 inches in thickness was laid, and lasted for many years, on the macadam roadway of Ashland Boulevard, Chicago, as far back as 1886, and similar construction was done in New York on Broadway between 59th and 93d Streets in 1889.

During the past thirty years there have been many instances of similar construction, particularly in cities, and there is no reason why this kind of foundation should not be used on important highways where the macadam, after being brought to subgrade, is of sufficient thickness.

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My experience has led me to conclude that each problem of road construction must be studied by itself, taking into account present kind and amount of traffic, with due allowance for future development, but not trying to foresee conditions beyond fifteen years. For this reason I doubt if any bonds should be issued for highway construction of greater maturity than fifteen years, and that provision should be made, through sinking fund or otherwise, to retire them during that period.

MR. BEEBEE, American Investment Bankers' Association:

I am very glad to have been able to be here to get the point of view which you gentlemen have on this subject.

I feel that there is really some constructive thought being given to this problem. So that you may understand the point of view I have approached this from, I will say that the firm I am now with has been a very large handler of securities of states and subdivisions, and as the years have gone by we have been brought more and more in contact with the economic problems of this road-building program. Furthermore, I have had the opportunity of doing what we believe is quite an important work along that line in connection with the chairmanship of the Municipal Securities Committee, so-called, of the Investment Bankers' Association, which has been working actively for many years to improve the laws, their application, character and various improvements throughout the country, and in the last few years I have been Chairman of the Legislative Committee of the same association, which has been working, not only with the other committees of the same association, but with a number of other public bodies, and particularly with public officials.

I simply cite that as showing that any suggestions I may have to make are not made purely from a personal viewpoint.

I want to call attention to the fact that years ago—I will mention and take this up from the county standpoint, because as a matter of fact that is where we most frequently meet this problem—years ago we used to consider that a county that is apart from one or more large cities, in itself had a reasonably large debt when it approached 5% of the assessed valuation of the property for taxation. As a matter of fact, 3% was regarded as about all they ought to have. That included jails, court houses, etc., and such expenditures as they had made up to that time for roads, and which for most part were simply dirt roads and were put in the annual budget.

Now, the last few years we have found in a great many of these states and counties that the enthusiasm for good roads has come in and they haven't hesitated to vote expenditures for road improvements alone which have approximated 10% of the entire taxable value of the county. Now, that may be a good thing, or it may not be a good thing.

In the old days we could almost pass by the question as to whether or not that indebtedness was wisely taken on in relation to the character of the improvement or not, because it was a more or less negligible percentage of the taxable values of the county.

(I am approaching it now more from the standpoint of the man who is going to invest his money in those securities.)

However, as time has gone on, and these debts have piled up—respective debts have piled up in the authorization of quite large amounts which are to be expended over a period of years, it becomes more necessary to make sure that as the years go by they are not going to pay for "dead horses" as is the saying, and it is at that point that our association has taken hold of this matter and has tried to influence legislation and the action of the public officials so they will give careful thought to the character of the improvements they were putting in, and their probable life.

We early came up against the question, as we found it principally in New York, Pennsylvania, and some of the first states who went into what you might call modern highway building, that little or no real attention was given to the maintenance problem. I think that all of us here in New York state can recall to mind how many millions of dollars of roads were put down,—I think you called it waterbound macadam, then the pavements and so on, for which there was no adequate arrangements made for maintaining that improvement after they had it.

The consequence was that a road that ought to have been maintained and kept in good condition for a long period of years was in a comparatively short span of years—some cases I myself have known—in not more than five or six years, found to be practically worn out and had to be rebuilt or entirely done over.

On the other hand, it has come to our attention—I think we have had some statistics from your department (Mr. MacDonald) indicating that under certain conditions, certain purposes, gravel roads or local hard-surfaced roads have been properly maintained and have been in good condition over a long period of years. I have known in one case in particular in the Carolinas, we were rather agreeably surprised to find roads that had been in twelve or fifteen years which to all intents and purposes were as good as if they were new roads, so that I think this problem from an economic standpoint is not only one of building roads, but it is of making an adequate appropriation and an adequate system of maintaining them.

It isn't only a question of raising this fund, but I might state as a sort of an interesting commentary on it, that I have been in the midst of a discussion recently by correspondence with the financial vice-president of one of the biggest insurance companies in the country. He is seriously considering not buying any of the bonds for road improvement purposes for any part of the country unless the laws require proper maintenance funds and proper arrangements for maintaining those roads.

Now, as to the probable life of a road, I think we will all agree that up to the present time there is no way in putting your finger on any set rule for that term of years which would see the practical use of that road. I know that my own concern for a good many years, and others in the same line, have felt that financing for roads should be confined to a period of not exceeding twenty-five and preferably twenty years, and we certainly want to see some adequate arrangements made either by the accumulation method of a sinking fund, or better yet, the serial payment method, to have the debt wiped out within that period.

There is no doubt in my mind but that the taxpayers will willingly submit to a liberal tax now, and in the next few years they are going to feel quite differently about it if they find the improvement that they have been taxed for is dead and gone and they have got to go through it again. I think the reaction will be very bad.

We know that the proper kind of a road—whether it be a gravel or clay road, or concrete road—put down where the traffic justifies it, is a matter of economics, and that we can well afford to stand a moderate tax, in order to have that improved road.

With regard to the national system we have felt that it was quite unfortunate that this particular appropriation for roads came along just when it did, because we have seen any number of cases where the various states had the idea—here is a chance to get something for nothing—and they have authorized expenditures for roads which are entirely disproportionate to their immediate needs, and particularly when the expenditure was incurred under the high cost of materials and labor prevailing in the last few years.

Possibly a concrete case or two will give you a better idea of what I mean. There is a certain highway which was projected from the Mississippi River west into Arkansas, which the engineer estimated would have a cost of approximately $62,000 a mile. The best bids they got on that work exceeded $70,000 a mile.

Now, I happened to know just enough about that section to know that that cost per mile simply meant that that state and that district—and it was one of these special assessment arrangements—couldn't possibly have very much mileage on that basis, and also that it seems almost ridiculous to think that they would put down roads that they contemplated would cost $60,000 a mile for the particular traffic which they had in contemplation.

I understand that one of the arguments made when they went before the various people in the district was that "the more we spend on this road the more we are going to get in the way of our state's quota from the Government aid fund."

There is a certain county, St. Johns, in St. Augustine, Fla., where the bankers and other business men are trying to convince the people that they should authorize an expenditure for road improvements to be put out in the next couple of years which approximates 14% of all the taxable values within that county.

Any conservative financial man is going to look askance at this proposition, and the money is either not going to be loaned or it is going to be loaned at rates that will be burdensome.

Another county is going through the same sort of educational campaign, although not so extreme in point of figures, but it does seem it is time that engineers like yourselves and our own association, the Investment Bankers, which includes practically all the representative people of the country, are liable for this thing, and that we should not only talk about it among ourselves but get out and make a noise in the open about it. It seems to me that that is the only way we are going to get down to a sane basis on this proposition.

I don't want to have it understood that we are against road-making or proper expenditure for road-making, but we do feel there is a proper perspective and proportion, which has got to be maintained if we are going to do anything more than go over the bank and collapse. (Applause.)

MR. E. E. REED, Assistant State Highway Engineer, New Jersey:

The state of New Jersey has a law which provides a direct state tax for the construction of roads in the state highway system. It is one mill on one dollar of valuation and returns about $3,000,000 a year for that purpose. This will run for five years, and expires in 1922, and it will return a total of $15,000,000. Well, that will be possibly one-fourth enough to pay for the cost of construction of the roads in the state highway system, so that you will see we will face at the end of 1922 a very serious economic problem, and there will have to be legislation at that time in order to give some relief.

Our roads are costing, on the basis of 45 miles having been recently finished and accepted, an average of $53,000 per mile. Some of those roads are in the southern section of the state where there is very little grading, and where you have a sand subsoil and not much drainage, the cost is from $35,000 to $40,000 per mile. In the northern section and central portions of the state they will go up to $100,000 per mile and more. The cost of the road going up the Palisades on the other side of the river will cost between $400,000 and $500,000 per mile. That, of course, is extremely expensive construction because it goes up the Palisades.

Where bad soil conditions are found, it has been the practice to excavate the bad material and place stone in the subfoundation. We have paid a lot of money for drainage, and we think that being one of the permanent features, it will be money well spent. The width of the pavement has been a minimum of 20 feet for two lanes of traffic established by the present commission, with a graded width of not less than 30 feet. The act establishing the state highway system provides for the latter width, with a minimum width of pavement of 18 feet.

The Engineering Department has provided a width of 29 feet for three lanes of traffic. The surfaces have been generally concrete, 6 inches at the side and 8½ inches in the center. On the routes carrying the main truck traffic the depth is 8 inches at the sides and 10½ inches in the center. Sheet asphalt and bituminous concrete on concrete foundations are also used, but mostly the concrete.

To do away with any openings in the pavements, it will be the policy in the future in those sections adjacent to towns, to place the Orangeburg fibre duct across the road about 4 inches in diameter and at intervals of practically 200 feet, and when anyone wants to lay a pipe across the road, he can pay a rental or a lump sum for the privilege of going through these ducts.

MR. J. V. DAVIES:

Mr. President, may I be permitted to ask the speaker if the mileage costs per mile of roads include any element of real estate, or is it purely construction?

MR. REED:

It is purely construction.

MR. MORRIS KNOWLES:

In Allegheny County, in October, we were suddenly informed that the county commissioners would present to the voters a $35,000,000 bond issue, to be voted upon November 2d. Most of that money is for highways or collateral improvements; that is, all but $1,000,000 which is to be devoted to some improvements of the court house.

The allowable bond limit by vote of the county commissioners themselves is 2%; 7% is permitted by popular vote, and this $35,000,000 will take about one-third of that 7%, perhaps a little more than a third. The local engineering organizations of the county, three of them, two sections representing national groups of engineers and one the local engineering society, have protested—protested upon the ground that there are no adequate plans. The fact is, there are no plans presented as to what highways are to be improved. The Board of Directors of the Chamber of Commerce at the suggestion of the Committee on Municipal Affairs and the Good Roads Committee, have unanimously protested, because, among other reasons, such matters should not be brought up at a national election and also because of the fact that there are a large number of new voters and because the time is short to educate the old voters, let alone the others who have not voted before.

Some of our states and many of the counties have bond issues running 30 or even 40 years. Again recent construction, from bond money, has been applied to roads for which bonds are still unpaid. It is evident the terms of bonds should more nearly correspond to the life of the roads.

And that brings me to the other suggestion—that one of the greatest needs is a definite plan and a separation of cost of grading and bridges from cost of superstructure.

In speaking of foundations, it may interest some of you to know I was told by the County Road Engineer of Allegheny County that most of the roads which failed recently due to heavy traffic were roads upon which the foundation had not been built according to design. They had been skimped.

We have not done enough to train highway engineers in this country.

We have regarded as secondary the subject of engineering in connection with road construction. The youth of this country should be trained to know how important highway engineering is, by having it taught in school in an elementary way.

MR. F. C. BROWN, Acting Director U. S. Bureau of Standards:

To come to the point of the whole resolution, how far is it well to proceed on a big program by haphazard methods, and how far is it advisable to spend effort in scientific investigations? I am rather a crank on that subject and believe that if we are to spend a billion dollars a year on the construction of roads, we should spend a very large percentage of this sum, if necessary, in order to establish the fundamental facts that enter into the construction of the highways. This work, however, can be more easily carried out, providing there is an organization such as the American Institute of Consulting Engineers to stand back of those who are doing the work and tell them to go ahead with it.

I should like to revert to an original statement by your President, and that is, that the government of the people should be thoroughly respected, and in order that this may be done it is absolutely essential that in the government and in every line of industry that is of major importance (certainly transportation is of the greatest importance in this country) there should be the highest grade of technical experts.

And if I were to amend your resolution, I would do so by way of suggesting that the Association pick three of the most able members and turn them over to the public service—even though they might have to be endowed for a while.

The Government is doing all it can, it it is only with your support that it can do more.

Mr. Thos. H. McDonald, Chief of U. S. Bureau of Public Roads:

First, let me direct your attention to the nature of our problem. It is not a question of whether we shall build brick highways or asphalt highways or dirt roads. What we are trying to do is to provide service—adequate highway service—and the engineers of this country must provide this service with all types of roads, but in any case the roads they build are going to be the very cheapest that will satisfy the demands of 8,000,000 motor vehicles, as well as horse traffic.

The specific problems which are raised by this heavy traffic so suddenly thrust upon us are: first, those relating to road construction and maintenance—the technical engineering problems; second, those relating to those qualities of the roads which are determined by characteristics of the traffic—by the operating requirements of the traffic—in which we are concerned with the type of road, maximum and minimum grades, the elimination of rise and fall, and curvature; third, those problems of economic value. Thus we have separated all our problems into three groups, and in regard to these three groups we have two major responsibilities, as I see it. First, we must develop certain fundamental information; and second, we must disseminate that information—we must put it into the hands of the men who will use it in building up this highway service, which is our objective.

Taking up the development of fundamental information—already a considerable amount of work has been done by the state highway departments, the Bureau of Standards and the Bureau of Public Roads. Under Mr. Page a great deal of work was done by the Bureau of Public Roads in devising methods of laboratory control of materials. This work was of such basic character that, although conditions have since changed very greatly, it was still of great value when the testing engineers of the state highway departments and the Bureau of Public Roads met recently to revise the standard methods of testing highway materials. The standards adopted by these gentlemen cover the testing of practically all highway materials, and represent the most approved practice.

They will be published very shortly by the Bureau of Public Roads.

It is highly desirable that these researches should be conducted on a national scale—that every agency capable of assisting in adding to our knowledge of these matters should be brought into co-operation, and its efforts directed by some coordinating agency to develop the essential information without lost time or duplication of effort. The one agency which seems best fitted to correlate and harmonize the individual effort is the National Research Council. Indeed that body has already outlined a program, and appointed committees to do this very work.

The section of the Research Council to which these committees report is the Engineering Division represented on which are such groups as the American Society of Civil Engineers, the American Society for Testing Materials, the Western Society of Engineers, the Society of Automotive Engineers, the American Association of State Highway Officials, the Bureau of Public Roads, and a number of others. It would seem that this Institute should be a member.

The tests we are now conducting at the Arlington Experimental Farm are revealing most valuable information as to the intensity of the impact caused by vehicles of various weights operated at varying speeds, with different loads, and distribution of load, and with different porportions of sprung and unsprung weight.

We have conducted thousands of these tests, until we can predict very closely what blow a given truck will deliver whether it drops an eighth of an inch or 3 or 4 inches, and whether it is traveling at 5 or at 15 miles per hour.

We have conducted another series of tests in which we have applied impacts of various intensities to road surfaces of different types; and as a result of these tests, I think we can say very definitely, right now, what thickness of slab of a given type is necessary to carry a 5-ton truck—at least we have established certain limits.

I may say that at the present time we are arranging to establish a laboratory in one of the Western States, not to find out how to build roads of such high types as you require in New

York State, but to find out how to build cheap roads properly. There are places in our Western country where the roads do not carry more than 15 automobiles a day. Yet roads must be built to accommodate what traffic there is.

The Bureau of Public Roads has regarded this, the national program of research on highways, as of so much importance that we should lend ourselves as part of the big organization; that is, submerge our identity in a big organization that is being formed to carry this on.

It would be most gratifying if your Institute would see fit to appoint a committee to make a visit to Washington and to go over experiments there.

We should be more than glad to have your whole membership come down, but assuming that would be an impossibility, we should be very glad if you would see fit to appoint a committee to make an inspection with the idea of offering constructive criticism.

Col. W. J. Wilgus:

We have heard for many years of the great benefits that accrue to the railroads through easy communication afforded by improved highways between the farming lands and adjoining industrial regions and the railroad centers. Beyond question that is true. There is, however, what seems to me to be a very much larger question that enters into the economics of the subject for discussion this evening, and that is the extent to which it is economical that the highways of the country should be generally improved at enormous cost for heavy motor trucks, for extremely long hauls, when the railroads exist for that very same purpose, and for which they have demonstrated their superior economy. Somewhere there must be the line to be drawn between the economical length of haul of the motor truck and that of the railroad.

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If the railroads can be improved in the future through some means of raising money, governmental or otherwise, I am among those who advocate that the railway terminals, the freight terminals particularly, should be banished to the outskirts of the cities, far enough removed to be away from the congested condition that I have mentioned, and connected with the centers of the city and with the industrial and consuming population by means of motor trucks or a combination of small car freight subways and motor trucks with demountable bodies. With a plan of this kind the highways radiating from our great centers of population should be so constructed as to be able to stand the heaviest kind of service,—say for a distance of thirty or forty miles. I believe that within that distance the motor truck will prove to be economical. Beyond that, as I say, I think the railroads should be improved and expanded to the end that they may come into their own again, and give to the public the cheap and efficient long haul service which they did in former years.

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Then that would leave for your highway routes stretching between distant points an adopted character of construction that would not run into the enormous costs required for heavy motor truck long-haul transportation.

MR. A. D. FLINN, Secretary Engineering Council:

I can safely say for Engineering Council, that, if you still desire, after this evening's debate, Council should serve you as you have suggested, it would attempt to perform that function as it has on other subjects.

Mr. MacDonald has already spoken of the research feature of your subject, to which I had thought of referring, as the Secretary of the Engineering Foundation, and ex-officio Assistant Secretary of National Research Council. I would ask whether your object would not be attained by requesting the Division of Engineering of the Research Council and the Engineering Foundation to perform these services for you as the existing research instrumentalities of the engineering societies.

MR. WHINERY summed up as follows:

Perhaps it was noticed in what I read that I laid special stress on elementary data. Now, it seems to me that that is what engineers require in any department of the work that they enter. Look at the history of our bridge design and construction. We didn't begin to build a bridge of thirty foot span and say ten feet depth of truss and take it out and try it, and see if it would stand up under certain loads. We began by investigating the properties of steel, finding out exactly what we could depend on from the material we had to use. We made an analytical investigation of the mechanical principles involved in bridge building and formulated the results. Combining the two things we were able and have been able and will continue to be able to design any bridge for any service.

No, it is all well enough to experiment at Washington on different kinds of roads, different depths of foundation and that sort of thing, and try them out in practice, or by experiment. Sometime we would doubtless arrive at conclusions in that way.

What we need and what the engineer demands, it seems to me, is elementary data. If somebody would take up the matter and investigate it thoroughly and tell us that under the conditions described in which I read, we can depend on a certain strength in a certain slab of concrete, and go on, with the investigation of soils for the subfoundation already begun and give us data as to how much under certain stresses a subfoundation will safely carry, we will be in a position to design our roads intelligently.

Now, give us those facts and such other facts as we need and we will take up this problem of designing roads just as we have that of designing bridges, and other things, and we will be able to say, if you tell us what service is to be required, whether a gravel or macadam road or asphalt road or granite block road with certain foundations will best serve the purpose and we will build them in such a way that you can depend on them. But, without that elementary data we are practically helpless.

MR. STILLWELL:

May I offer an amendment to the resolution? In order to introduce this subject and take into account what Mr. MacDonald in particular has told us in regard to the proposed action of the National Research Council, I would offer the following amendment to Mr. Whinery's resolution:

Resolved, That the resolution as read be adopted in principle; that it be referred to the Council with instructions to broaden the scope of the proposed investigation as it may deem proper, and to determine what steps should be taken with a view to securing the desired results.

My thought is that we should broaden the resolution to include particularly the broad economic aspects of the problem which have been referred to by Colonel Wilgus.

After discussion, a point of order was raised that a quorum was not now present. An informal vote was taken, however, in respect to the sentiments of the meeting, with the unanimity of opinion that the matter should be referred to the Council.

The meeting adjourned at 11:45 p. m.

Dr. J. A. L. Waddell submitted his discussion and suggestions in writing, reading in part as follows:

The people of our country, and especially its engineers, are in dire need of a thorough and exhaustive treatise of the highest type of technical literature on "Economics of Highway Construction." There is no one man capable of writing such a book, nor does there exist the necessary information to prepare a satisfactory treatise on the subject.

In order to accomplish what I have in mind, there should be selected with the greatest possible care three engineers as a permanent committee to direct the making of an exhaustive investigation, co-ordinating the energies of all present experimenters, investigators, and writers upon the subject, and eventually preparing the treatise mentioned. Two of these men should be highway engineers of the highest standing who have shown an interest in investigations for their specialty, and who are capable of writing good technical English; and the third should be an engineering economist of acknowledged standing—preferably, if such there be, one who has specialized in highway work.

If our Council should decide to adopt this suggestion of mine, the first step for it to take would be to notify the membership of its decision; and the next would be to write officially to the secretaries of all organizations of any importance, which make a practice of formally interesting themselves in highway building, including the leading local engineering societies of the country, requesting their endorsement of the movement and their help at Washington in securing the necessary legislation with an appropriation that would be ample for the purpose in view.

Since the meeting of October 13, 1920, the subject has progressed as follows:

November 10th the Council adopted the following resolution:

WHEREAS, The design, construction and maintenance of highways is one of the most important matters now occupying the attention of the American people, and the money expended annually for highway improvement aggregates an enormous sum; and

WHEREAS, Experience has demonstrated that a large majority of the new and improved highways built in the past under designs, specifications and methods still being largely adhered to, are inadequate in strength and endurance to withstand the weight and density of the travel, and their consequent rapid disintegration and failure results in great financial and economic loss; and

WHEREAS, The unsatisfactory and costly experience of the past has been largely due to the lack of accurate data relating to the physical, mechanical and economic problems involved, such as has been accumulated by adequate scientific investigation in other departments of engineering work, and

WHEREAS, The great financial and economic magnitude and importance, and nation-wide character of this department of public work warrants and demands the most careful research and study, and such research is an appropriate and proper function of the National Government, therefore be it

Resolved, That the Federal Congress be requested and strongly urged to authorize and direct the Secretary of Agriculture to set aside and appropriate, out of any unexpended balance from the sums appropriated by Congress under the Federal Aid Road Act of 1916 and the amendments thereto, a sum not to exceed three hundred thousand dollars, to be expended in research to supply the physical and economic data needed for the intelligent and efficient design, construction, maintenance and operation of highways; said research to be conducted under the authority and control of the Engineering Division of the National Research Council by a commission, appointed by the said Engineering Division, of three men, who shall devote their whole time to the work, and shall receive adequate compensation for their services.

Resolved, That the co-operation and active aid of other engineering, technical, economical and commercial organizations, the Highway Commissions of the several States, and the public press be solicited in securing the early inauguration and furtherance of the program herein outlined.

At a conference on Highway Research, organized at the instance of the National Research Council, Division of Engineering, Messrs. S. Whinery and F. A. Molitor represented the Institute, and presented the resolution named above. This conference organized an Advisory Board of Highway Research, which is fully set forth in the following article received from its Secretary:

The Council at a special meeting held on November 19th heard the report of its representatives submitted by Mr. Whinery as follows:

"REPORT OF THE REPRESENTATIVES OF THE INSTITUTE TO THE CONFERENCE UPON HIGHWAY RESEARCH,
HELD NOVEMBER 11, 1920.

"TO THE COUNCIL:

"Your representatives to the Conference of the Engineering Division of the National Research Council held on November 11th, offer the following report:

"Both representatives attended the conference at which, in addition to members of the Engineering Division of the National Research Council representatives were present from the U. S. Bureau of Public Roads, The American Association of Highway Officials, the American Automobile Association, the American Society for Testing Materials, the Western Society of Civil Engineers, the Engineering Council, the S. A. E., and officials of several State Highway Commissions, and members of the faculties of a number of universities. There were in all about 40 present. The meeting was devoted to the necessity of and the methods proposed for a thorough investigation of the elementary principles and factors entering into the problems and practice of highway engineering.

Your representatives presented the resolutions adopted by the Council on November 10th and advocated the general scheme outlined therein. While no formal action to adopt the plan was taken it was very favorably received and commented upon. But several who spoke during the general discussion expressed the opinion that the financial resources in sight and promised would be sufficient to meet the cost without resort to government appropriations; and the prevailing sentiment seemed to favor the direction of the work by special committees each being assigned to some one or more branches of the research, a central office to be maintained in charge of an efficient secretarial force."

A NATIONAL PROGRAM OF HIGHWAY RESEARCH

There are in the United States over 250,000 miles of railway, over 2,000,000 miles of highway, 7,000,000 passenger automobiles, and nearly 1,000,000 motor trucks.

Highway traffic has increased so rapidly both in quantity and intensity that old methods of road building fail to meet demands. Indeed, even our most modern highways do not long withstand the destructive action of some of our heavily loaded trucks.

The Federal Government, the States (and their subdivisions) are planning expenditures totaling nearly a billion dollars a year for roads. But nobody yet knows how to build roads for present-day traffic, on the widely variant kinds of natural foundations, in the extremely different climatic conditions, at reasonable cost, with the much-to-be-desired permanence.

There is urgent need for a systematic, thorough, comprehensive research program which will place our road building on a sound scientific engineering basis and enable the country to spend effectively the large sums involved. The savings which can surely be effected by the knowledge which can be gained only through research will aggregate tens of millions, *provided this knowledge can be gained and used from the early stages of the road building program.* The cost of the research, intelligently directed would be insignificant in comparison, although a million or two may be required.

The need is realized in many quarters and several agencies are at work; but their work is as yet uncoordinated, incomplete and overlapping. To meet this need and to conserve the research talent as well as the material resources of the Nation, the Division of Engineering of the National Research Council undertook to organize a National Highway Research Program. In this work the Division was aided and encouraged by the U. S. Bureau of Public Roads. In order to secure co-operation of the numerous existing agencies and through such co-operation to bring about the concentration of the talent of the country and avoid duplication, the Engineering Division called a general Highway Research Conference on November 11th. To this conference were invited representatives from a number of organizations of national importance interested in highway construction, Governmental and State departments, and higher educational institutions.

At this meeting a General Advisory Board on Highway Research was organized and by-laws adopted. Quoting from these by-laws, it will "assist in outlining a comprehensive national program of highway research and co-ordinating activities thereunder; organize committees for specific problems; deal with ways and means; and act in a general advisory capacity. In addition to certain administrative committees the Board voted to create the following four research committees:

(a) Bibliography
(b) Economic Theory of Highway Improvement
(c) Structural Design of Roads
(d) Character and Use of Road Materials

Other committees will be added as the problems can be formulated and suitable men found.

It is the intention of the Advisory Board on Highway Research to secure a definite assignment by Congress of a certain portion of the unexpended balance of federal-aid road money to some agency which will administer the funds under the direction of the Advisory Board. It is hoped that sufficient funds may immediately be made available to allow the research work to begin at once, with the employment of a corps of highly trained research men, the best obtainable. One of the outstanding features of the conference was the feeling that a large percentage of all moneys now available for highway construction could be saved were effective research work done quickly and the results widely spread.

During the conference, three reports of research committees of the Division of Engineering were heard, together with several short discussions as to the need for research in highway matters. Thomas H. MacDonald, Chief of the Bureau of Public Roads, pointed to the fact that but one per cent. of the Federal budget for the fiscal year ending June 30, 1920, had been expended upon research and of that amount 63% had gone to the Department of Agriculture. Of the total budget 3% represented money available for public works and of that amount 59% was to be spent for highway construction. With a program calling for the expenditure of more than $1,000,000,000 on highways now under way, he stressed the necessity of making as clear as possible the solution of the fundamental problems upon which the economic expenditure of this money rested.

Both Professor Adams and Professor Marston emphasized the need for co-operation in research matters and the prompt action necessary in starting a national program on Highway Research.

A list of the national organizations that are being asked to appoint representatives to the Advisory Board on Highway Research of the National Research Council are as follows:

Bureau of Public Roads, Department of Agriculture.
American Association of State Highway Officials.
War Department—Motor Transport Corps.
National Automobile Chamber of Commerce.
American Institute of Consulting Engineers.

University Highway Engineering Departments.
Division of Geology and Geography of National Research Council.
National Highway Traffic Association.
American Society of Civil Engineers.
American Society for Testing Materials.
Society of Automotive Engineers.
American Society of Mechanical Engineers.
American Association of State Geologists.
American Concrete Institute.
American Railway Engineering Association.
American Society of Municipal Improvements.
American Automobile Association.
Western Society of Engineers.
Federal Highway Council.

Other suitable organizations may be invited to have representation in the Advisory Board, whenever the necessary information about them comes to hand. Co-operation of the state highway departments is also being sought.

At the same meeting Mr. S. Whinery was appointed representative of the Institute to the National Advisory Board on Highway Research, and F. A. Molitor alternate.

The officers, by direction of the Council, will submit the resolution named above to the Chamber of Commerce of the U. S. A., asking them to submit it by referendum to its constituent members.